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# Highlights of Sandia's Photovoltaics Program

Sandia National Laboratories

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TOPICS THIS QUARTER



WORLD WIDE WEB
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**In this issue, we feature Sandia's system assistance and technical testing.**

## Focus This Quarter: Million Solar Roofs and Reliability Issues

In June, President Bill Clinton inaugurated for the nation the "Million Solar Roofs" initiative. According to U.S. Energy Secretary Pena in the Million Roofs initiative, the administration will use federal purchases, lending programs, and research to carry out the plan to put solar roofs (photovoltaic and water heating systems) on 1 million U.S. buildings by the year 2010.

Research underway by the DOE-funded National Center for Photovoltaics, including both Sandia and the National Renewable Energy Laboratory, has focused on providing a sound technological base for widespread deployment of photovoltaics.

In this quarterly, we publish snapshot reports to illustrate the system assistance and technical reliability testing for which Sandia is well known, the kind of work that will be essential to the success of this White House initiative.

## The Value of Battery Energy Storage in Shifting Time-of-Day Use of Photovoltaic Energy

The concept of shifting photovoltaic energy in utility-tied systems from when the energy is available to when it has the highest value has been discussed often. Sandia was recently involved in a program with the Salt River Project, a Phoenix, Arizona-based utility, to evaluate this concept. The evaluation involves an occupied residence in Chandler, Arizona — known as the Chandler House — which was chosen because the home and load are representative of a broad class of residential customers and the homeowner is receptive to having utility employees occasionally enter his garage or climb on his roof to check on the system.

The Chandler House installation includes a photovoltaic system of 2.4 kilowatts (Solarex modules) with 25.2-kilowatt hours of battery energy storage (Trojan L-16 batteries). A Trace inverter is used because of its ability to be programmed for various "buy" and "sell" periods, as well as its ability to interface with photovoltaics, batteries, and the utility. The main purpose of this project was to test the ability to store energy during one selected time and then discharge that energy during another time. The Trace inverter allowed this to be done quite easily, and this concept proved to be a success. The system is designed to use all the electricity produced by the photovoltaic system; thus, the value of the electricity is the retail value at that location in Arizona.

A secondary objective was to examine the economics of the process. This required monitoring the energy on a continuous basis, then applying various economic factors to the energy produced and either stored or fed to the load. This information was then analyzed using both Salt River's standard flat rate and an experimental time of day rate that the utility has developed. The summer time-of-day rate is as follows:

| | | |
|---|---|---|
| Off Peak | 11 p.m. - 11 a.m. | $0.0403/kWh |
| Shoulder | 11 a.m. - 2 p.m.;<br>7 p.m. - 11 p.m. | 0.0991/kWh |
| On Peak | 2 p.m. - 7 p.m. | 0.1720/kWh |

The summer flat rate, which is Salt River Project's standard rate for a home like the Chandler House, and which is used as a comparison in evaluating this project, is $0.0899/kilowatt-hours.

The results of this analysis are summarized in a table (see page 2). The entry $1161 represents the average residential customer with a home similar to the Chandler House. Note that if this average customer uses the experimental time-of-day rate and does not adjust his energy use patterns to take advantage of that rate, the annual cost of energy increases. This is exactly what a time-of-day rate is supposed to do — provide financial incentive to the customer to change energy-use patterns. Also, note that the least cost option to the customer (considering energy cost only, not considering installation cost) is photovoltaics only using the standard flat rate. There is very little difference between any of the other three options, but they all have higher annual energy costs than photovoltaics

| | Annual bill with no photovoltaics or batteries | Annual bill with photovoltaics only | Annual bill with photovoltaics and batteries |
|---|---|---|---|
| Standard Flat Rate | $1161 | $906 | $987 |
| Experimental Time-of-Day Rate | $1213 | $975 | $980 |

***Analysis of energy-shifting, Salt River Project.***

only. Why is it that the use of a battery to shift energy to the peak-rate hours results in a higher energy bill than a batteryless system? There are actually several areas where one could examine the system in detail and find means of improving economics of photovoltaics + battery system economics, but the biggest factor is in the battery losses. A review of the data over the first 14 months of operation shows total electrical losses from the system (that is, from photovoltaic output to ac out of the inverter) of roughly 40%. If one assumes that about 15% of these losses are in the inverter and wiring, then that implies 25% losses in the battery.

This is a bit of a surprise because the battery-charging strategy was designed in an attempt to minimize the losses in battery charging, while still charging the battery in a manner to maintain good battery health. This strategy consists of bringing the battery to about 85% state of charge each day (using photovoltaic energy), then discharging the battery during the daily peak. The Salt River Project has no peak times on the weekends, so every second weekend the battery is equalized to eliminate problems with sulfation and stratification.

Sandia and Salt River plan to continue with this project to determine means of increasing the value to the customer of battery energy storage in photovoltaic systems. There is certainly value to the utility in having the customer store energy during off-peak periods, and then discharge that energy during on-peak periods, but the process must also be of value to the customer.

*For more information, please contact John Stevens 505-844-7717.*

***Photovoltaic system at Chandler House, near Phoenix, Arizona.***

## A System Approach to Reliability Improvement for Grid-Tied Systems

An ongoing Sandia study of grid-tied photovoltaic systems has shown that although system availability is high, inverter problems, coupled with maintenance response time, contribute to reduced availability. The data indicates that quality control for inverters in the study reduces system reliability. Also, observed repair times, which were especially long due to the long lead time in staffing a service position, added to reduced availability.

***A 4-kilowatt residential grid-tied PV system being studied by Sandia.***

The purpose of this study is to identify the reliability of grid-tied photovoltaic systems with the aim to eventually improve system reliability. Reliability is not characterized by a single measure, but encompasses many measures including mean time between failures, availability of the system, length of down-time following a failure, and the costs to operate and maintain the system. The systems described here are a collection of 106 identical 4-kilowatt residential grid-connected units purchased and installed by a utility (Sacramento Municipal Utility District) on private homes in 1993 (see photo). The systems are serviced by the utility following requests from the homeowners and meter readings.

Sandia modeled these systems using actual maintenance data to provide statistics on their operation. The mathematical representation can then be used in "what-if" studies with different maintenance and component reliability conditions to determine the best ways to improve system reliability.

### *Modeling grid-tied systems*

The system approach uncovers opportunities for improving reliability based on reliability statistics. By statistically characterizing the operation of a system, it is possible to say which system failures have the most impact on the various measures of reliability. First, "system failure" must be defined and data collected to show the frequency and duration of these system failures. Collecting data on a number of similar systems provides statistics on the uncertainties in the different measures of reliability. Finally, it is important to know what costs are being incurred in operating and maintaining the systems, including both scheduled and unscheduled maintenance, as a result of failures. With these three types of information, the system being analyzed can be simulated by a computer model, which can then be used to show which system improvements will be most effective in improving the different measures of reliability.

In the current study, a failure was defined as a complete loss of power production from the system. Although this excludes certain failure events that may only reduce or degrade system power production, this definition was selected for the practical consideration of being able to identify a failure without a costly system-by-system survey. Loss of system output was detected by a monthly meter reading or by the homeowner.

Estimating the uncertainty in the collected failure rate data for each observed failure mechanism is as important as having good failure rate data itself. A mechanism with a low failure rate but high uncertainty (wide error band) may be more significant than a mechanism with a higher failure rate but a low uncertainty. Both inherent variations in the rate of a given failure mechanism and measurement inaccuracies contribute to this uncertainty. Fortunately, the software used in this reliability modeling effort, a code called WinR developed at Sandia for analysis of microelectronics, can be applied to photovoltaics and provide support here. The computer model reveals the contribution of each failure mechanism and its uncertainty to the failure rate and uncertainty of the whole system. Consequently, one can focus data collection efforts on those mechanisms that have the most impact on the full system performance.

### *Reliability and grid-tied systems*

When plotting the system's mean time between failure, one can see that a majority of the systems will operate 6 to 10 years without incident (see Fig. 1). However, 5-10% of the systems will fail during the course of a typical year. The bimodal (double-peaked) behavior of the histogram indicates that some failures affect only a certain fraction of the systems while not affecting the entire population. Because the inverter is by far the largest contributor to the failure of these grid-tied systems (see Fig. 2), a quality control problem probably exists that causes some inverters to fail more often than others.

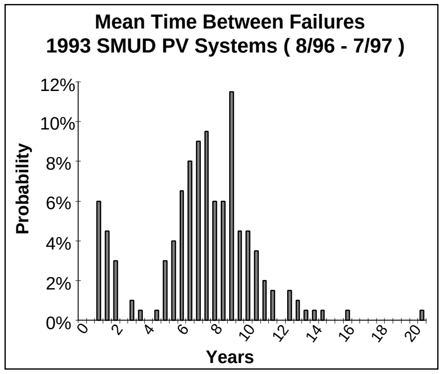



*Figure 1.*

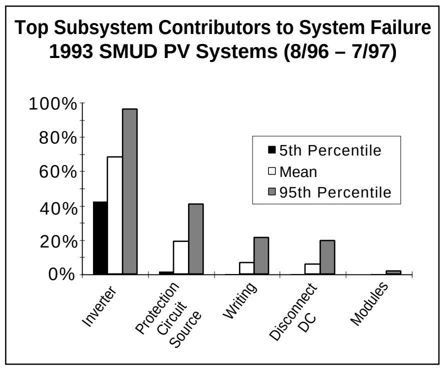



*Figure 2.*

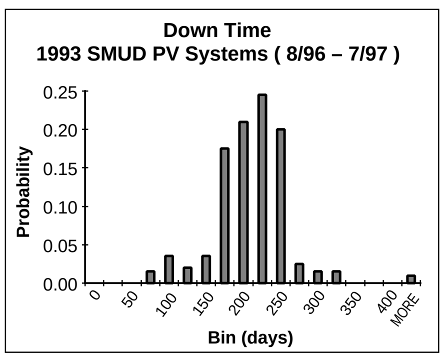



*Figure 3.*

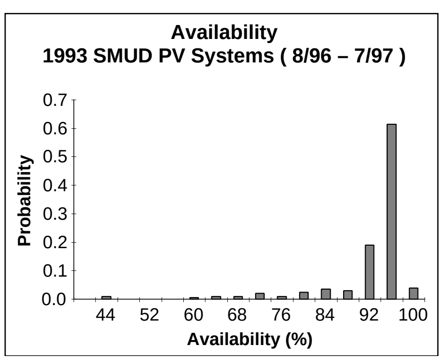



*Figure 4.*

A second finding is that the average down-time of the system between a failure's occurrence and its repair was about 6 months (see Fig. 3). The down-time includes both problem reporting and problem repair time. Although meters monitoring the photovoltaic system's production were read monthly, for many months at the beginning of the monitoring period no technician was available to service the failed systems. Now that a service technician is on board, response time is expected to improve to under a month.

Resulting system availabilities vary widely, ranging from 40% to 97% with about 85% of the systems having an availability greater than 90% ( see Fig. 4). Availability for this study is the fraction of time that a system is able to produce output power. By reducing down times with faster responses, the 15% of systems with availability less than 90% can easily be brought up. Note: Comprehensive cost information on repair is still being gathered, thus cost of maintenance has not yet been characterized for these systems. This information is expected soon.

*For more information, please contact Alex Maish, (505)844-8771 or Chris Atcitty (505)844-6567.*

## Newest "Renew the Parks" Project Includes Photovoltaics and Sustainable Building Design

A photovoltaic array at Salinas Pueblo Missions National Monument is the newest project in Sandia's Photovoltaic Systems Assistance Center "Renew the Parks" partnership with the National Park Service. Located some 60 miles southeast of Albuquerque, NM, the system at the new Visitor's Center for Gran Quivira, one of three units that make up the monument, was dedicated in June and is now open to the public.

The system consists of a 1.44-kilowatt array of 24 Solarex MSX-series photovoltaic modules, a Trace 5-kilowatt sine wave inverter, and 4-kilowatt hours of valve-regulated lead-acid batteries. The system is tied to the local grid service of Central New Mexico Electric Cooperative, and it can provide additional power when needed. The solar energy system

***Newly installed photovoltaic system at Salinas Pueblo Mission National Monument in New Mexico.***

includes a back-up dc battery with an ac converter that can provide uninterruptible power in emergencies.

Springer Electric Cooperative supplied the system through the Photovoltaic Services Network; Springer, as well as eleven other electric cooperatives across the state serving rural customers, is affiliated with the local service provider. Direct Power and Water, an Albuquerque company, is providing installation and maintenance services. A noteworthy aspect of the new system is the fact that it is a standardized, packaged system available through the Photovoltaic Services Network and its network of 50 member utilities. Also worthy of note is that the system is used as a photovoltaic-powered uninterruptible power supply for computer, security, and other emergency loads at the Visitor's Center.

The National Monument at Salinas is featuring the system as an important part of its interpretive experience for visitors. Springer Electric Cooperative recently developed and implemented a photovoltaic service program to provide its customers the option of using a photovoltaic system for high-value applications at locations throughout New Mexico. This is the first system in that program.

The Department of Energy's photovoltaic program, through Sandia, provided technical support and contributed $10,000 toward the project. Also funded by the Department of Energy through Sandia, Southwest Technology Development Institute at New Mexico State University supplied an interactive computer kiosk on the renewable energy elements of the Visitor's Center, which is the first in the National Park Service to specifically follow and incorporate sustainable design practices and building features. They include use of recycled ceramic tile, recycled auto-windshield floor tile, recycled Styrofoam and concrete wall members, high-efficiency lighting, passive solar design, water-conserving appliances, renewable electric power, and minimum impact siting for the building.

Monument Superintendent Glenn Fulfer and Facility Manager Mike Schneegas said that the partnership with Sandia helped the National Park Service plan greater efficiency into the building. Cost of the photovoltaic system was about $18,000, including a 5-year, full-service agreement.

*For more information, please contact Hal Post (505)844-2154 or Mike Thomas (505)844-1548.*

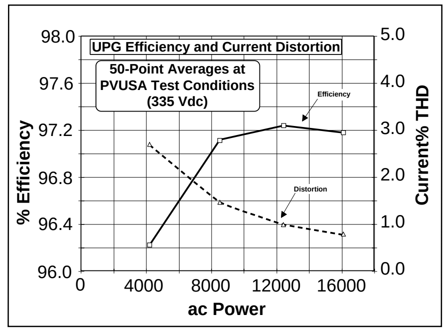
## Sandia Supports PVMaT in Laboratory Development Testing of Grid-Tied Inverters

### Introduction

Sandia has performed development testing of several inverters in support of the PVMaT manufacturing initiative for balance-of-system components. The three PVMaT inverters designed for grid-tied applications included a 20-kilowatt high-efficiency unit from Utility Power Group (UPG) and module-scale inverters from Ascension Technologies and Solar Design Associates (SDA). The inverter component of the SDA unit was provided by Advanced Energy Systems (AES). The products are being refined as a result of this development testing.

### UPG 20-kW high-efficiency prototype

The UPG inverter had an ac output voltage of 173 Volts ac line-to-line, which was stepped up to 480 Volts ac to be connected to the Sandia building utility grid. A photovoltaic simulator was used as dc power source. Because of its high switching frequency, the inverter operated with virtually no audible noise and had a relatively small size and weight for its power rating. Efficiency, harmonic distortion, power factor, disconnect time (islanding), and surge response were characterized. Issues were identified with respect to islanding disconnect time and surge response. The following figure shows efficiency to be more than 97% and distortion to be less than 1.5% for output powers more than 8-kilowatts. The combination of this performance with integral photovoltaic mounting hardware make this a unique product.

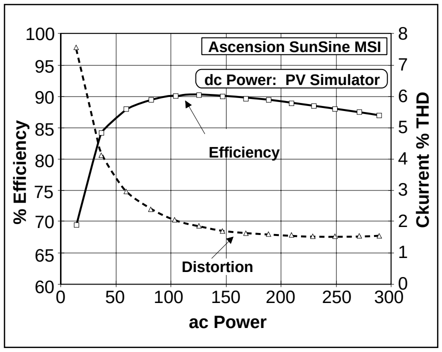



***Efficiency and distortion of UPG grid-tied inverter.***

### Module-Scale inverters

Module-scale inverters are mounted on the back of a photovoltaic module, providing an ac power source as an integral package. The Ascension SunSine 300 is mounted on an ASE Americas module, whereas the AES MI-250 is mounted on a Solarex module. Both are presently being operated continuously in on-going long-term tests at Sandia with multiple grid-tied inverters on a single ac branch circuit. Manufacturers are being provided with performance information, including output power levels, efficiencies, operating temperatures, and islanding disconnect times. Pre-production issues have been identified with islanding times, surge protection, and ac overvoltage disconnect.

At the request of Ascension, a SunSine 300 pre-production prototype was detached from its module and characterized. A photovoltaic simulator, a dc power supply, or the module itself were variously used as dc sources. Comparisons were made to design specifications, including energy loss at night, efficiency, ac current limit, distortion, voltage and frequency trip points, ripple current, and maximum power point effectiveness. The figure that follows shows the efficiency and current distortion of the SunSine 300 powered by a photovoltaic simulator.




***Efficiency and distortion of prototype Ascension module-scale inverter.***

### *Conclusion*

Testing at Sandia has accelerated the development cycle by providing valuable information to developers of grid-tied PVMaT-funded inverters. In addition to on-going long-term testing, follow-on comparisons will be made as the products continue to evolve and move into production. Other grid-tied inverters not directly involved with PVMaT are being tested as well, and more are being added. These include both module-scale (few hundred watts) and residential-sized (few kilowatts) units. A major goal of this testing is to provide information for use in the development of utility-interconnection standards such as IEEE 929.

*For more information, please call Jerry W. Ginn (505) 845-9117.*

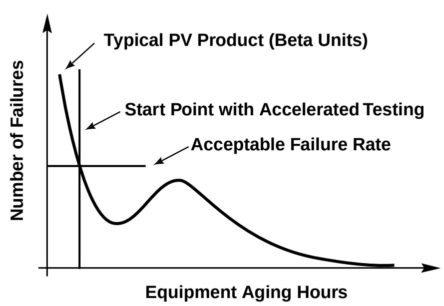
## *Sandia Uses Accelerated Testing to Improve Reliability in Electronics Hardware*

As a part of its program to improve the reliability of fielded photovoltaic systems, Sandia is acting as facilitator between accelerated lifetime test laboratories (such as QualMark) and photovoltaic manufacturers. Sandia has provided funding for the initial accelerated testing of some photovoltaic products. A typical test on a component costs $11,000, takes 200 hours for the humidity test and about 30 hours for the vibration, temperature, and electrical stresses.

To date, Sandia has sponsored the testing of two prototype photovoltaic products; evaluations of three more products are planned. As a result of highly accelerated testing of the Ascension Technology module-scale inverter, 20 weak points were identified. Solutions included design changes, production procedure changes, and changes in component selection. During evaluation of the Advanced Energy Systems module-scale inverter, 19 weak points were identified. Action as a result of testing included rejection of bad connectors, software rewrite, new epoxies and mounting techniques, and the use of higher temperature wires.

### *How accelerated testing improves product strength*

The plot of product failure as a function of time (hazard rate curve) resembles a roller coaster, with a high number of early failures followed by humps later in life (see figure below). Because the quantity of products for photovoltaic applications is typically low, many photovoltaic products, especially those in grid-tied applications, never get off the initial steep portion of the curve. Accelerated testing will precipitate many of the latent defects and reduce the failure rate to an acceptable level.




***Product failure as a function of time.***

### *Highly accelerated testing*

Highly accelerated testing consists of a series of evaluations that apply increasing levels of stress up to the limits of technology. During this process, it is anticipated that the product will fail, be repaired, and fail again. The evaluations are preferably conducted several times during product development, with the last of the tests being performed on early production models.

For each problem identified during evaluation, it is critical that the root cause of failure be determined and corrected. It is important to stress the product beyond specifications to the limit of the technology. Although there is often resistance to “over stress,” there is ample evidence that this approach avoids field problems.

Because of the variable strength of a latent defect, as many units as possible should be tested. This will aid in finding those defects that lie at the lower edge of the product stress distribution. Some of the benefits of accelerated testing are that it saves manufacturing cost, reduces development time, lowers life cycle cost, improves reliability, lowers repair costs, and establishes limits of operation (necessary for stress screening). Accelerated testing may include elevated temperature, temperature cycling, power cycling, electrical, vibration, humidity, combined environment, and others, as appropriate.

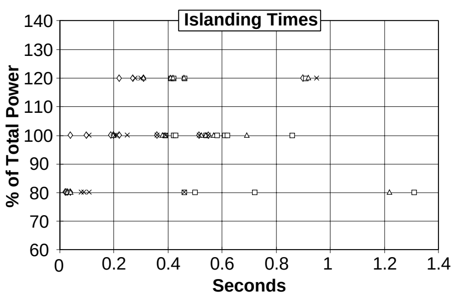
*For more information, please contact Russell H. Bonn, (505) 844-6710*

## *Sandia Evaluates Grid-Tied Inverter Islanding*

As a portion of its grid-tied inverter benchmarking, Sandia is evaluating the anti-islanding capabilities of several grid-tied inverters. The test configuration involves the evaluation of four grid-tied inverters (operating at approximately rated capacity), connected in parallel, on the same utility line. Each test was conducted consecutively (10 minutes apart). This configuration addresses the concern of multiple inverters of different types on a single distribution feeder. Under such a scenario, it was speculated that the additional inverters could maintain a condition that disables their ability to readily identify an interruption in the utility feeder. The inverters evaluated were the Omnion 2400, Sanrex, AES MI-250 version 1.2 module scale, and Ascension Technology’s Sunshine 300 prototype module scale inverters. (Note: the MSI inverters are prototype models). The Trace 5548 PV inverter was on-line Aug 1.

### *Islanding tests*

The islanding tests are initiated by interrupting the utility line. A software-activated relay opens a 60-ampere contactor, which provides 120/240 Volts ac to the inverters and the local loads. Islanding times (the time it took each inverter to disconnect from the grid) are recorded in seconds for each unit. With all inverters operating, their combined power is approximately 6.6 kilowatts; therefore, at 120 Volts ac the maximum interrupted current is approximately 55 amperes. Thus far only 120 Volts ac inverters have been installed, allowing for the desired parallel, single feeder configuration. The figure below displays most of the islanding times seen by each of the four inverters with the local load set at 80, 100, and 120 % of the total power output of the combined inverters. It was anticipated that local loads greater than the total output power would cause a faster disconnect; however, there has not been a distinct pattern established during the islanding tests.




***Islanding times seen by each of the four inverters with the local load set at 80, 100, and 120 % of the total power output.***

The duration a grid-tied inverter is allowed to stay connected to the utility after a interruption has not been clearly defined by any standard. Therefore, the islanding times seen may not be of concern. The longest observed islanding time exceeded 10 seconds for all 4 inverters. Because the distribution transformer may play a role in inverter disconnect time, future test results will include data with a contactor on the utility side of the distribution transformer. The condition for this test was a load approximately equal to the total output power of all the inverters. It is anticipated that a matched, pure resistive load will increase the islanding times. Islanding tests including a pure resistive load will be reported on in a future issue of these highlights.

*For more information, please contact Fred Gonzalez (505) 845-8942.*

## *The Module Durability Research Cooperative: Applying Science to Enhance Module Lifetime*

The Module Durability Research Cooperative, Sandia's industry/laboratory team that studies the lifetime of commercial photovoltaic modules, has been in existence for 18 months and is experiencing increasing requests from an expanding customer base. The reliability of photovoltaic systems is of concern as demand for them grows and applications become more commonplace. Sandia has for decades been responsible for the reliability of the nation's weapons stockpile, and the Laboratory experience in this area matches one of the critical needs of the photovoltaics industry.

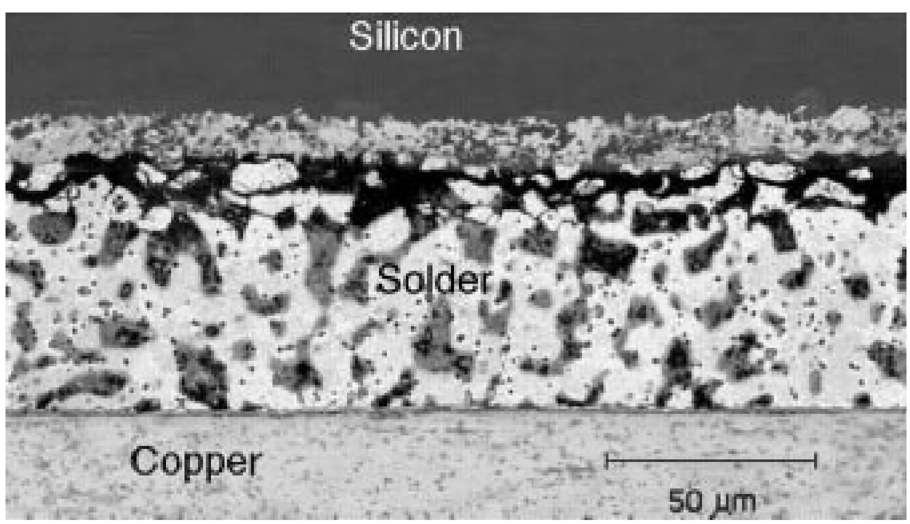
Already, solar and other manufacturers have realized the benefit from Sandia's ability to tap into technologies developed for defense applications. In fact, Sandia recently employed defense-related technologies and experience to evaluate solder joints, measure the tensile modulus of encapsulants, and search for evidence of hydrolysis in encapsulant from field-aged solar modules. In addition, a method Sandia developed for cutting tempered glass is being examined for its applicability to reliability studies. Finally, Sandia's photovoltaic program is utilizing previously acquired experience and combining it with newly developed techniques, such as Module Dark I-V tests, to further investigate module reliability issues.

Two types of tests performed at Sandia are outlined here to give illustrate what can be done in the laboratory to enhance and ensure reliability in the field.

### *Characterization of solder joints*

One of the technologies being used extensively in the laboratory to test module reliability is characterization of solder joints (see photo that follows) using metallographic techniques. Poor or failed solder joints increase series resistance in modules, causing hot spots and decreasing performance. Solder joints are being extracted from field-aged photovoltaic modules, examined, and compared to joints from modules directly off the manufacturing line in Sandia's Photovoltaic Systems Evaluation Laboratory's test facilities.

This technology will soon be implemented at the root level as the Module Durability Research Cooperative works with the Spire Corporation to characterize a new Spire Assembler currently being manufactured. A controlled experiment will be conducted to produce solder joints under varied parameters.




***Example of a solder joint.***

Characteristics of these joints will be compared to joints produced by the current process and joints from field-aged modules. This effort will allow Spire to understand the degree with which the assembler should control processes and allow the manufacturer to optimize the soldering process for the specific soldering process. In addition, the manufacturer will understand if the assembler is producing joints comparable to previously manufactured joints.

### *Module Dark I-V and infrared scanning*

Sandia has developed a Module Dark I-V test technique, fixture, and software that is instrumental in determining the series resistance of photovoltaic modules. This technique, developed as a result of experience with our Cell Dark I-V technique, is providing valuable information when used to characterize field-aged modules. This technique has potential use as an in-line manufacturing testing method for module manufacturers.

The Module Dark I-V test derives resistance by applying voltage to a module in the reverse direction. The current is allowed to float to a stable point, then, current and voltage are recorded. After multiple points have been measured, the software can derive series and shunt resistance values. The fixture also allows for testing at standard operating temperatures. Information from this test technique is then compared to acceptable values, and candidates for further testing can be selected.

Candidates for further study can then be subjected to infrared thermometry. A set current is passed through the module in the reverse direction while the module is scanned with an infrared camera to determine the location of hot spots. These locations then become the candidates for extraction and solder joint characterization.

*For more information about these tests, about Sandia's test capabilities, or about the Module Durability Research Cooperative, please call David King (505)844-8220 or Michael Quintana (505)844-0474.*

## *Yuma Proving Ground's Photovoltaic System Combines Functional Capabilities of Stand-Alone and Grid-Tied Systems*

Utility Power Group completed construction of a 900-kilovoltampere (kVA) utility-tied photovoltaic power station for the Yuma Proving Ground (see photo) in September 1997. The system, which was funded in phases through the Department of Defense's Energy Conservation Improvement Program and Strategic Environmental Research and Development Program (SERDP), includes 400 kilowatts (at PVUSA test conditions) of Siemens M-55 modules, 5600 kilowatt-hours of C&D motive power batteries, and a 900-kVA Trace Technologies power processing system and system controller. This is the first system to combine the functional capabilities of both stand-alone and grid-tied photovoltaic systems. It will supply the grid with up to 375 kilowatts of ac power directly from the photovoltaic array, supplement that with battery power to supply up to 925 kilowatts for maximum peak shaving benefit, and power a critical water treatment plant during utility outages. These functional capabilities provide the maximum possible benefit from a grid-tied photovoltaic system.

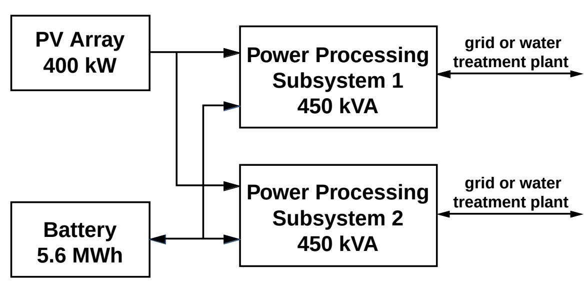
***900-kVa utility-tied photovoltaic power station for the Yuma Proving Ground.***

A block diagram of the Yuma system is shown below. The 900-kVA power processing system consists of two identical 450-kVA subsystems. Each 450-kVA subsystem consists of two 225-kVA inverter/rectifiers; a master and a slave. Each 225-kVA inverter/rectifier includes a 225-kVA photovoltaic maximum power tracker and a 225-kVA bi-directional dc/dc converter for the battery. The photovoltaic array and battery are divided into two halves. One half of the array and battery feed the master maximum power tracker and battery dc/dc converters, and the other half feeds the slave power tracker and battery dc/dc converters, a configuration that provides both flexibility and reliability through redundancy. The system's operation is described below.

In the grid-tied mode, all photovoltaic power is sent directly to the grid to realize its maximum benefit. The operator can increase the power supplied to the grid via a programmable output profile. If the desired output is 450 kilowatts or less, both the photovoltaic and battery power are inverted in either one of the two 450-kilowatt power processing subsystems. If the desired output is greater than 450 kilowatts, the photovoltaic power is inverted in one subsystem and the battery power is inverted in the other. This strategy provides better loading of the power processing units, which results in better system efficiency. The batteries are charged from the grid at night from one or both power processing subsystems.

The system will automatically switch from the grid-tied mode to the stand-alone mode in the event of a utility outage, and it will automatically switch back to the grid-tied mode when utility service is reestablished. In the event of a utility outage, the system shuts down while the water treatment plant is electrically isolated from the grid. The system then restarts in the stand-alone mode using one of the power processing subsystems. As in all stand-alone systems, photovoltaic power in excess of the demand of the water treatment is used to charge the batteries.

The system was procured through two contracts, a $3.85M Energy Conservation and Improvement Program contract




***Block diagram of the Yuma system.***

through the U.S. Army Corps of Engineers for a 450-kilowatt utility-tied system, and a $1.6M SERDP contract through the Naval Facilities Command for the advanced capabilities, second 450-kilowatt power processing unit, and battery storage subsystem. As technical investigators for the SERDP effort, Sandia devised the concept and requirements for the advanced capabilities upgrade. As technical advisors for DoD's Photovoltaic Review Committee, Sandia assisted with technical specifications, design reviews, and acceptance testing for both the Army and Navy contracts.

*For more information, please contact Rick Chapman, 505-844-0859.*

## BRIEFS

Sandia's WWW site has a new address. Please visit us at www.sandia.gov/pv

New material has been added, and the site has been reorganized to make material easier to find. Some of our listings include

- PV components
- Balance of system
- System design
- Projects — lists of projects and success stories
- System operation
- Library: glossary and on-line publications
- Photovoltaics quarterly highlights and announcements
- Answers to frequently asked questions about photovoltaics
- Feedback page — a way to communicate with Sandia's Photovoltaics staff
- A search function

***Sandia creates and distributes a variety of publications on photovoltaic systems and their applications. For a list of these documents, please contact the Photovoltaic Systems Assistance Center:***


*through e-mail:* *pvsac@sandia.gov*

*by phone:* *505-884-3698*

*by FAX:* *505-844-6541*

*by mail:* *Photovoltaic Systems Assistance Center*
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**Forward and address correction requested**




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